MixNet results on the macaque cortex network

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Presentation of the dataset. The dataset of [1] consists in 47 brain cortical regions connected by 505 inter-regional pathways in the Macaque Cortex. As brain function is based on inter-regional connections, studying the way cortical regions interact may offer new perspectives in the comprehension of information flows within the brain. It appears that particular brain regions may play different roles: some regions can be at the "center" of a particular part of the network, meaning that a lot of information will pass through them, whereas other parts of the network may be more "peripherical". Consequently, identifying central zones would be important, as their lesion may compromise the integrity of the whole network.

From a topological view, finding those "hubs" as focused much attention, with a definition based on degree only. However, there exists many ways for a node to be a hub, and degree is one criteria. As there is no definition of what a hub is, there are many different hubs (provincial and central). This is why [1] developed a multi-criteria strategy to find nodes that can be called "hubs". From a methodological point of view, this approach seems to be limited as the resuting hubs will be criteria-dependent.

The gain of Mixnet is that the model can be used to find those hubs. Indeed, using the underlying missing data framework, MixNet will find nodes that connect heavily to other nodes in the network, and that share this connectivity pattern (a class of hubs for instance).

Interpretation of MixNet results. When using the ICL criterion, 8 groups are selected. Results are illustrated in Figure 1, and in Table 1 which gives the estimated parameters of the model as well as. The first result is that node V4 makes a group on its own (group 3). It constitutes a "core" node or a provincial hub, which is highly connected to other groups. The most connected are groups 1 and 2, which are distinguished by MixNet whereas this part of the network is considered as an homogeneous module by [1]. The split can be explained by the intensity of connection to group 3 which is different ($\hat{\pi}_{1,3} = 100\%$, $\hat{\pi}_{3,1} = 100\%$, $\hat{\pi}_{2,3} = 71.4\%$,$\hat{\pi}_{3,2} = 42.9\%$), but also because their connection with group 4 is different as well. Similarly, note that groups 1 and 3 form a clique which is split because of each group's connections to other zones in the brain.

The intensity of connection to group 4 is very different for groups 1 and 2: $\hat{\pi}_{1,4} = 43.7\%$, $\hat{\pi}_{4,1} = 6.2\%$, $\hat{\pi}_{2,4} = 85.7\%$,$\hat{\pi}_{4,2} = 92.8\%$. This means that there is a strong difference of intensity between the two groups, and the direction of the flow is also different, as group 1 sends more connections than received, whereas the flow is nearly balanced for group 2.

Group 4 is made of 2 nodes which can be considered as a set of hubs. Node FEF (Frontal Eye Field) is known to receive and send many long range pathways, whereas node 7a merely connects visual and sensimotor group (poly sensory integration). Interestingly nodes of this group allow the communication between groups that do not connect to each other : groups 3-7, 3-6, 6-2, 6-1, and 1-7 communicate only via their connection to group 4. Therefore group 4 is the group of connector hubs, and even if the functions of the two zones of group 4 are not the same, their similar connection pattern indicates that the lesion of those regions could lead to the same consequences in terms of information flow.

Group 7 is made of hubs with Ig not declared as a hub by [1] based on different criteria (just below the limit), whereas MixNet emphasises that its connectivity pattern is a "hub" pattern. Group 7 can also be considered as a group of "connectors" since groups 6 and 8 communicate only through group 7.

From a histological perspective, V4 mediates information flow between two groups of areas, one belonging predominantly to the dorsal visual stream (groups 1 and 2) and the other belonging to the ventral visual (group 5, without MP and MIP). Consequently, the partition given by MixNet can also be related to geographic areas in the cortex. This can be explained by the geographic organization of the connections within the brain. Similarly, a majority of zones of groups 6 7 and 8 belong to the parietal frontal lobe which corresponds to somatosensory and motor areas.

It is worth being noted that the network of brain cortical regions is highly connected, with few between-classes connections lower than 1% (See Figure 1). It means that the majority of cortical regions are inter-connected with different intensities, which is not always the case in biological network which are more sparse in general.

References

[1] Sporns O., Honey C., and Kotter R. Identification and classification of hubs in brain networks. *PLOS one*, 10:1–14, 2007.

	1	2	3	4	5	6	7	8
1	75.0	58.9	100.0	43.7	2.8	3.6	10.0	.
2	44.7	76.1	71.4	85.7	3.2	12.2	25.7	.
3	100.0	42.9	45.7	50.0	55.5	28.6	20.0	.
4	6.2	92.8	50.0	100.0	11.1	42.9	100.0	.
5	4.2	6.4	66.6	27.8	23.6	4.8	4.4	.
6	8.9	12.2	28.6	42.9	12.7	76.2	31.4	1.8
7	15.0	45.7	.	80.0	6.7	42.9	100.0	45.0
8	.	.	.	18.7	.	7.1	62.5	57.1
alpha	17.0	14.9	2.1	4.3	19.2	14.9	10.6	17.0

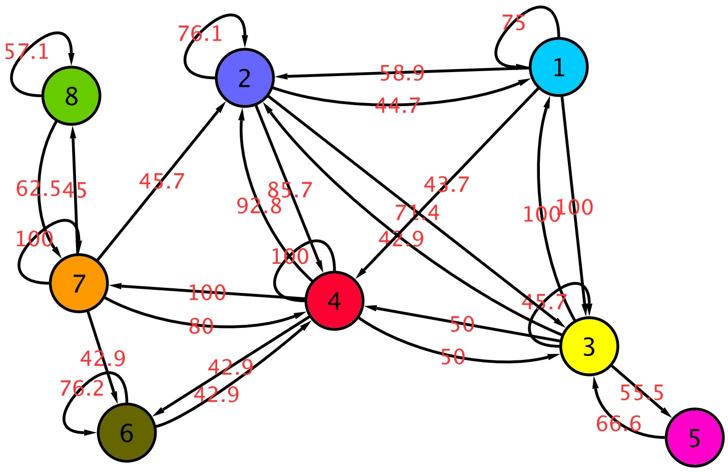

Figure 1: Top : MixNet parameters for the macaque cortex network with $Q = 8$ classes. Dots in the table correspond to connections ($\times 100$) lower than 1%. Bottom : each node represents a MixNet group, and edges are labelled according to $\hat{\pi}_{q\ell}$s. Edges corresponding to $\pi_{ql} \leq 32\%$ are not displayed.

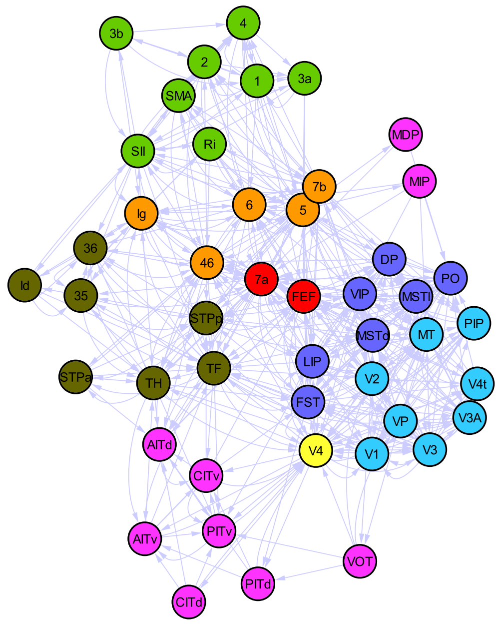

Figure 2: Macaque cortex network displayed with colors for each MixNet class (8 groups).